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Description

Method and circuit arrangement for current measurement

The invention relates to a method for current measurement in accordance with the precharacterizing clause of patent claim 1. In addition, the invention also relates to the associated circuit arrangement.

One known method for current measurement involves measuring the voltage drop across a shunt resistor. Digital/analog converters (ADCs), which convert the analog measurement signal into a digital measured value, are frequently used in modern measuring and switching devices for the purpose of measurement. In this case, the following problems may arise:

a) The measurement signal has a high dynamic range, since small currents (< 10% of the rated current) still have to be measured with an acceptable resolution and large currents (≥ 10 times the rated current) also still have to be detected.
b) Accuracy must not be inadmissibly impaired by the effect of ambient temperature.
c) The electronic components (ADC, processor etc.) need to be supplied with current. In this case, two (DC) decoupled power supplies are frequently required, since there are components both at a low potential (zero potential or artificial star point) and at a high outer conductor potential.
d) In addition to the outer conductor current, the outer conductor voltage must also frequently be measured against zero potential.
e) In the event of an overload or a short circuit, the main circuit must be disconnected.

The applicant's earlier specification DE 101 05 982 A1, unpublished at the priority date of the present

application, discloses a method of the type mentioned initially, in which a measurement signal is at a higher potential than zero potential and there is a measuring device that requires a supply current, the measurement

signal occurring in the form of an analog value and its measurement information being transmitted, after A/D conversion, in the form of a digital signal to an evaluation unit which is at ground potential, and, after A/D conversion of the measurement signal, the digital signal produced providing the clock for modulating the supply current, which thus likewise performs the function of the carrier for the information content of the measurement signal. In order to overcome the abovementioned problems, the following measures are taken in this case:

a) High dynamic response: analog/digital converters having a linear characteristic curve and a correspondingly high resolution (number of bits) are used.
b) Effect of ambient temperature on accuracy: (expensive) special alloys which have a low temperature coefficient are selected for the shunt.
c) The voltage is supplied directly to an ADC at a low potential using either voltage converters, i.e. transformers, or voltage dividers.

On the basis of the facts above, it is an object of the invention to propose technical improvements for a method of the type mentioned initially and to provide a suitable circuit arrangement for this purpose.

The invention achieves the object by virtue of the measures of the method claims. The arrangement claims specify associated circuit arrangements.

The invention is essentially characterized by the following measures and features:

a) Dynamic response: the ADC is not implemented with a linear characteristic curve but rather with a rounded characteristic curve. As a result, the

measurement signal is compressed and a smaller number of bits suffices for the same dynamic response. This method, which is known as compression, is thus intended to be advantageously applied to current measurement. Possible characteristic curves are logarithmic characteristic curves (with

special handling of the zero point), which have the advantage of constant relative accuracy, i.e. errors relative to the measured value, or a root function, which affords the advantage of simple expansion by means of squaring, for example in a microcontroller.

b) Effect of ambient temperature on accuracy: a special resistance alloy is not selected for the shunt but rather use is made of a piece of rail which is present anyway and comprises conductor material. In order to increase the resistance (for the shunt) locally, the cross section is reduced by means of constrictions. The high temperature coefficient of copper is compensated for by virtue of the ADC having a reference voltage which has a temperature coefficient that, as far as possible, is of the same magnitude and is synchronous. The measuring unit, which is at a high potential anyway, can be installed in such a manner that it is in good thermal contact with the copper rail used, so that both are at the same temperature level.

c) Voltage supply: DE 101 05 982 A1 (already mentioned), entitled "Verfahren zur Auswertung eines Messwertes und zugehörige Schaltungsanordnung" [Method for evaluating a measured value, and associated circuit arrangement], relates, inter alia, to a method for current measurement at potential, in which to obtain the supply current for the components which are at potential directly from the system and to transmit the measured value at a low potential by modulating the supply current. This basic idea can now advantageously be expanded to the effect that, in addition to the supply current for the components at a high potential, the supply current for the components which are at a low potential is also obtained directly from the system. In order to prevent the power loss from becoming

unnecessarily high, some of the voltage dividers may also be implemented using nonreactive resistors and some may be implemented using capacitors.

d) Outer conductor voltage measurement: the outer conductor voltage is measured with the aid of a voltage divider which is present anyway. To this end, either the voltage drop across the upper resistor R_{Lx} is supplied at potential to an

additional channel of the measuring device or the voltage drop across the lower resistor R_x is supplied at a low potential to an ADC in the evaluation device. In this respect, reference is made specifically to figure 6, which is described further below.

The following advantages over the prior art are achieved, in particular, with the invention:

a) High dynamic response: the proposed method has the advantage that lower-cost ADCs which do not have to provide a high resolution over the entire measurement range can be used.

b) Effect of ambient temperature on accuracy: the proposed method has the advantage that an expensive special alloy does not have to be used but rather use is made of a piece of rail which is present anyway and comprises conductor material. In addition, fastening (screwing, riveting) of the resistor element to the copper is dispensed with. High measurement accuracy is nevertheless achieved as a result of temperature compensation.

c) Voltage supply: the proposed method has the advantage that the costs, weight and space requirement are reduced.

d) The voltage drop across the resistors occurs anyway in the case of the current-measuring device described and can thus be used in a cost-effective manner for the additional voltage measurement using simple means.

Further details and advantages of the invention become apparent from the figure description (below) of exemplary embodiments with reference to the drawing in conjunction with the patent claims. In the drawing:

figure 1 shows the arrangement of a measuring device, which has a shunt at a high potential, and the shunt resistor,

figure 2 shows a logarithmically compressed code for use in the measuring device shown in figure 1,

figure 3 shows a logarithmically expanded measured value for use in the measuring device shown in figure 1,

figure 4 shows, as an alternative to figure 2, a code which has been compressed in accordance with a square root curve,

figure 5 shows, as an alternative to figure 3, a measured value which has been expanded in accordance with a square function,

figure 6 shows an arrangement for measuring the current and voltage in a three-phase system, and

figure 7 shows an alternative arrangement having means for short-circuit and/or overload disconnection.

The text below is based essentially on the earlier specification DE 101 05 982 A1, the disclosed content of which is part of the present subject matter of the application. Irrespective of this, however, the subject matter of the application can be applied to current and voltage measurement in generalized form.

Figure 1 shows one advantageous arrangement of the shunt resistor and measuring device. In accordance with figure 1 in DE 101 05 982 A1, a phase L1 that is at a high potential contains a shunt 1 which uses an amplifier 2 to provide an analog/digital converter 3 (as part of a measuring device 5) with the measurement voltage U_{diff} 1. The voltage difference U_{diff}, which is regarded as being a measure of the current through the shunt 1, is converted by the analog/digital converter (ADC) 3 into a binary measured value and is transmitted at ground potential in the form of a binary signal. Connected upstream of the ADC 3 is a unit 4 for signal compression which can be used, in particular, to take a high signal dynamic response into account in a cost-effective manner, the binary signal being subjected to reverse expansion after it has been transmitted. Said

expansion can be effected at ground potential using software in the relevant evaluation unit, particularly in the microcontroller which is usually provided.

In the case of current measurements using a shunt, the effect of ambient temperature on accuracy is known and should not

be ignored: the shunt resistance is dependent on temperature in accordance with the following function:

$$R_s = R_0(1 + a*T) \qquad (1).$$

Figure 1 is furthermore used to show that, by thermally coupling the shunt 1 and measuring device 5, the temperature response of the shunt resistor is compensated for by a temperature response of equal magnitude from a reference voltage source 6 with a function corresponding to that for the resistance:

$$U_{ref} = U_0(1 + a*T) \qquad (2).$$

Figures 2 and 3 show the signals for logarithmic compression/expansion and figures 4 and 5 show those for root/square compression/expansion. 21, 31, 41 and 51 are used to denote the relevant characteristic curves.

Figure 6 shows a measuring device for measuring the current and voltage in a three-phase system having phases L1, L2 and L3. The evaluation channel for L1 has been set out in full but the identical channels for L2 and L3 have been set out only partially. The fundamental factor in this case is that the individual channels contain three identical shunt resistors 61, 61′, 61′′ which are each connected to a measuring unit 60 that corresponds to the measuring device 5 shown in figure 1.

Both the voltage supply at a high potential and the voltage supply at a low potential are obtained from the system using the voltage divider 66, 66′ and 67, 67′. Resistors 69, 69′ at a high potential and further switching elements such as capacitors and blocking diodes are furthermore provided, with 64, 64′ being used to denote the means for signal rectification as a whole.

The switching elements which are used to effect the

desired signal compression and signal expansion (which is the inverse of the latter) in accordance with the characteristic curves shown by way of example in figures 2 to 5

is integrated in the measuring unit 60 in figure 6.

In figure 6, the neutral conductor N is connected to the loads 70, 70′, 70′′, and a star point is formed. Alternatively, the three voltage dividers form an artificial star point in the switching device when the neutral conductor is not connected, which, for reasons of cost, corresponds to the normal situation.

The voltage drops across the lower and upper resistors may alternatively be used to measure the voltage. If the upper voltage is being measured, the two measured values, i.e. current and voltage, are transmitted at a low potential using the modulated supply current.

Figure 7 shows the design of a circuit arrangement having a measuring unit 60 in accordance with figure 6. The shunt 71 having circuit elements 72 uses a control unit 73 and a rectifier 74 to drive voltage dividers: specifically, voltage dividers have been constructed in this case from resistors 76, 76′ and 77, 77′ and alternatively 79, 79′, the current being supplied either at a high potential or a low potential.

Connected downstream of the amplifier 2 (provided in figure 7 in accordance with figure 1) and the AD converter 3 is a differential amplifier 78′ which is capacitively coupled to the voltage dividers via capacitors (which are not denoted further).

Means for short-circuit and overload disconnection are additionally provided: for this purpose, the circuit contains, in addition to the elements which have already been described, an apparatus comprising two comparators 85 and 95 having two threshold values which are independent of one another and can each be set. The first comparator 85 compares the instantaneous current value with the threshold I and, in the event of said

threshold being exceeded, outputs a signal for short-circuit identification

which can be used to disconnect the main circuit. The second comparator 95 compares the instantaneous temperature value of the load (which value is obtained using a thermal model 94) with the threshold II and, in the event of said threshold being exceeded, outputs a signal for overload identification which can be used to disconnect the main circuit. Just one of the two comparators may also be provided.

The parallel voltage dividers having the resistors 76, 76′ and 77, 77′ and 79, 79′ use a differential amplifier 78 to provide the evaluation unit 75 with a signal at a low potential. The evaluation unit 75 may be a microcontroller and corresponds to the unit 65 shown in figure 6.

The described method with the associated circuit arrangement is particularly suited to measuring the current at potential and evaluating the measurement signals which occur, at a higher potential than zero potential, in the form of an analog value and whose measurement information, after A/D conversion, is transmitted in the form of a digital signal to an evaluation unit which is at ground potential. In this case, the digital signal produced provides the clock for modulating the supply current and thus likewise performs the function of the carrier for the information content of the measurement signal. Rounded characteristic curves are advantageously used to compress/decompress the signals. Suitable means for temperature compensation are likewise provided.